Silica Aerogels for Microelectronics Applications

Lowest dielectric constants for fast electronics

Silica (silicon dioxide) aerogel consists of bonded silicon and oxygen atoms joined in "beads" linked randomly together with pockets of air between them. Discovered in the 1930s, silica aerogels were at first dismissed as laboratory curiosities. With improved processing techniques, such as those developed at LLNL, aerogels are now on the verge of commercialization.

High-speed microelectronics

The microelectronics industry requires faster and faster signal propagation. Dielectrics used in electronics packaging and in ultralarge-scale integrated circuits are evolving rapidly as performance demands increase. With a dielectric constant (ε) as small as 1.008 (nearly that of air), aerogels are more than a factor of 3 faster than alumina ($\varepsilon \approx 10$), the dielectric commonly used in multilevel ceramic circuit boards.

The trend in industry is to move to polyimide ($\varepsilon \approx 3$) or other polymeric dielectrics. Polymers, however, have large thermal expansion coefficients (CTE) that can lead to warping and stress. Aerogels can be made with a CTE of 3 ppm/°C, closely matching that of the silicon substrate and thus resulting in less stress.

APPLICATIONS

- *High-speed electronic conductor substrates for both ultralarge-scale integrated circuits and interconnections between computer chips*
- *Microwave circuits such as those used in radar and telecommunications*
- *High-speed gallium–arsenide test chips and associated electronics packaging*
- *Extremely lightweight electronic packages*

On the leading edge of aerogel-dielectric technology

We have developed processes to seal, pattern, and metallize both bulk and thin-film aerogels. We have made and characterized thin-film aerogels 1 to 10 µm thick and can seal the aerogels from subsequent semiconductor process liquids so that conventional photoresist techniques can be used. We have patterned aerogels with plasma-etching techniques and sputtered thin (<0.5 µm) metal layers onto the aerogel surfaces and electroplated thicker (>1.0 µm) layers. We have patterned metal conductors on top of thin-film aerogels on silicon substrate.

Patterned, 4-µm-wide gold conductors on thin-film aerogel.

Inexpensive, rapid processing

Silicon thin-film aerogels are made using a patented process involving a silica solution (with the consistency of oil) to which water, a solvent, and a basic catalyst are added to form a gel. The ungelled solution is spun onto a silicon wafer in a manner similar to that used to spin on conventional photoresists in semiconductor processing. The silicon can be dipped into the solution or the solution can be allowed to fill the space between substrates. The gels are dried through supercritical extraction of the solvent. The resulting layers can be made in thicknesses of 1 to 100 µm. Our laboratory-scale process takes hours; other processes can take days.

Availability: Silica aerogels are available now. We are seeking industrial partners to collaborate on developing these aerogels for microelectronics and related technologies.

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